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Technical Lesson 48

PRACTICAL RADIO CONSTRUCTION

We now come to the subject of stabilization in tuned radio-frequency amplifiers. Stabilization is a term applied to the various methods employed to suppress the highly undesirable oscillations which radio-frequency amplifiers are so likely to produce. The methods used to suppress oscillations in radio-frequency amplifiers are numerous, but can be classified under two general headings; (1) methods which accomplish their purpose by the introduction of resistance in the amplifier circuits, and (2) the methods which prevent oscillations through the use of circuits designed to establish a condition of electrical balance.

Of these two general methods the latter is by far the more preferable for such circuits can be adjusted to a condition of electrical balance without necessarily introducing electrical losses; whereas, on the other hand, those systems which suppress oscillation in a radio-frequency amplifier by the use of resistances are fundamentally and essentially less efficient because the very presence of resistance in such circuits causes loss of valuable signal energy. These methods are generally termed "losser" methods—the derivation of the term being obvious from the immediately preceding considerations.

This lesson will deal with a method of suppressing oscillation in a radio-frequency amplifier by one of the approved "balance" methods; for there is no gainsaying the statement that such balancing methods constitute the best engineering practice.

Oscillation in a radio-frequency amplifier tube is caused solely by feed-back from plate to grid circuits and if such feed-back could be completely eliminated oscillation would be non-existent. Unfortunately the very structure of the tube, as well as the operating characteristics of the circuits associated with the tube, renders it impossible to achieve such a complete isolation of the plate and grid circuits. There remains but one alternative and that is to do what we can to minimize the causes of feed-back and then to apply corrective measures to off-set the harmful effects of that remaining. Having minimized feed-back as much as circuit and receiver design will permit, the problem of successfully combating the remaining feed-back is somewhat simplified.

The principle causes of oscillation in a radio-frequency amplifier have been set forth in Lesson 36 and, before continuing with this lesson, it would be well to review briefly the points emphasized in that lesson.

Referring to Figure 1, in order that the radio-frequency amplifier tube give maximum response to an incoming signal it is necessary that its grid circuit be tuned to exact resonance with that signal by proper adjustment

of inductance L_1 , and condenser C_2 . When circuit L_1C_1 is thus resonated, the incoming signal will cause maximum fluctuation of the grid voltage of the tube. These changes in the tube's grid voltage cause comparatively large fluctuations in its plate current; and as this fluctuating current flows through the plate coil P it causes corresponding changes in its magnetic field. Inasmuch as coil P is coupled to coil L_2 , any variation in the strength of its magnetic field will induce voltages in coil L_2 . Because L_2 is the grid coil of the detector tube it is essential, in order to secure maximum response, that the voltages induced therein by coil P be as great as possible.

This is accomplished by using a condenser in shunt to coil L_2 and adjusting it until circuit L_2C_2 is in resonance with the frequency of the amplified signal energy flowing in coil P . This automatically brings circuit L_2C_2 into resonance with the grid circuit L_1C_1 inasmuch as both are tuned to resonance with the same signal frequency.

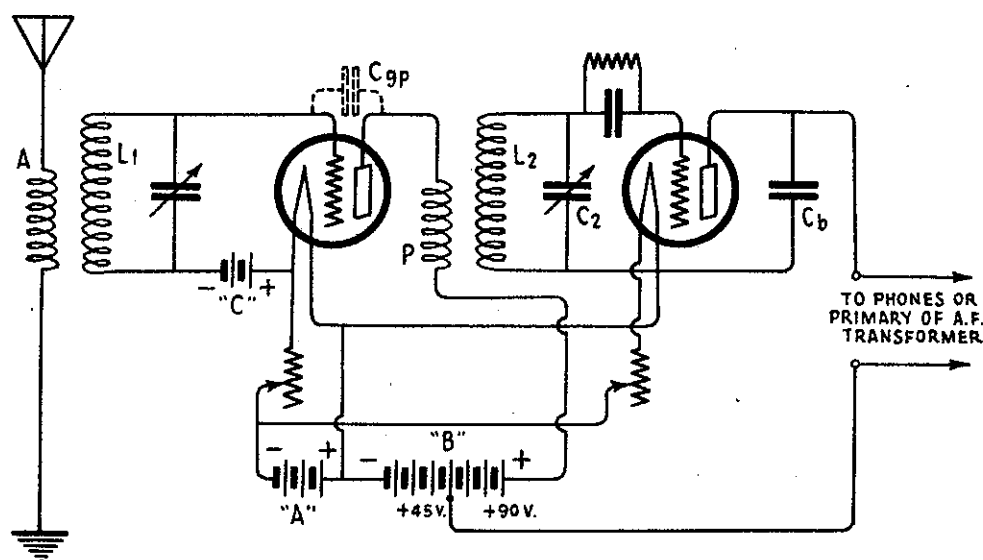


Figure 1

The fact should not be overlooked that, since the tuned circuit L_2C_2 is inductively coupled to coil P , the circuit L_2C_2 will also serve to tune the plate circuit of the radio-frequency amplifier tube; the extent to which the tuning effect of circuit L_2C_2 will make itself felt upon the plate circuit of the radio-frequency amplifier tube being dependent upon the degree of the coupling between these two coils.

This point may not seem to be of importance until one recalls what takes place when the plate and grid circuits of a tube are tuned to the same wavelength. As stressed in previous lessons, when the grid and plate circuits of a tube are in resonance, oscillation is the inevitable result.

In a circuit such as that in Figure 1, wherein is shown a stage of tuned radio-frequency amplification followed by a vacuum tube detector, it can be readily appreciated that in order to receive a signal it is essential

that the grid and plate circuits of the radio-frequency amplifier tube be brought into resonance with each other. The resulting oscillation of the radio-frequency amplifier tube could be stopped by either loosening the coupling between coils P and L2 and thereby decreasing the tuning effect of circuit L2C2 upon its plate circuit; or by detuning circuit L2C2 and thereby throwing the grid and plate circuits of the radio-frequency amplifier tube out of resonance with each other. This latter method, however, cannot be employed in this instance inasmuch as circuit L2C2 is not only a part of the radio-frequency amplifier tube's plate circuit, but it is also the tuned circuit connected to the grid of the detector tube. Such being the case, if the circuit L2C2 is detuned to an extent great enough to cause oscillations in the radio-frequency amplifier tube to cease, the detector's grid circuit tuning, which is controlled by this same tuned circuit, L2C2, will fail to respond appreciably to the incoming signal.

Our only recourse then is to that control of oscillation provided by varying the coupling between coils P and L2. This method of oscillation control is effective, but it possesses the formidable disadvantage of being a variant with wavelength. The operation of the receiver described in Lesson 36 demonstrates that the critical degree of coupling between coils P and L2, which gives maximum signal strength without oscillation, is much less when the receiver is tuned to the shorter wavelengths in the vicinity of 200 meters than when tuned to the longer wavelengths of about 500 meters; therefore, it must be varied each time the tuning of the receiver is changed in order to realize full amplification and hence secure maximum signal strength. This means an additional variable control and where but one stage of R.F. amplification is made use of this additional control is not objectionable for, by enabling the user to keep the tube just below the oscillating point and thereby realizing the full benefits of regeneration, it justifies its inclusion in the receiver. But, in receivers where two, three or four stages of tuned radio-frequency amplification are used, to make use of variable coupling between the primary and secondary of each inter-stage radio-frequency transformer is quite out of the question for the simple reason that the resultant multiplicity of controls would render the tuning adjustments of the receiver a painstaking task even for a person fully conversant with the operating characteristics of such a receiver; to the average broadcast listener tuning such a receiver would be a labor of Hercules. For this reason, receivers are almost invariably built with fixed coupling between the primary and secondary windings of the inter-stage radio-frequency transformers.

In view of foregoing considerations, the degree of coupling between primary and secondary must be made sufficiently loose so that oscillation does not occur at the shortest wavelength to which the receiver is designed to respond. This loose coupling is usually secured by using very few turns of wire in the primary winding, four to eight turns being the number used in the radio-frequency transformer primaries of many receivers. Hence, the number of turns of wire in the primary winding are few in order to keep the coupling sufficiently loose so that the radio-frequency amplifier tube will not oscillate at the lowest wavelength to which the tuned circuits will be resonated; in this case 200 meters. Although the transfer

of signal energy from primary P, to secondary L2, will be poor with such loose coupling, the receiver, nevertheless, will be capable of good amplification at the shorter wavelengths near 200 meters. This is because at these short wavelengths the radio-frequency amplifier tube is near the oscillating point and the consequent regeneration will compensate for the looseness of coupling between P and L2.

As the receiver is tuned to longer wavelengths regeneration decreases very rapidly and soon disappears entirely; and at the same time the transfer of energy from P to L2 also decreases markedly. Thus, the amplification of the radio-frequency stage decreases rapidly with an increase in wavelength until, at the higher wavelengths in the vicinity of 500 meters, the radio-frequency amplification is but a mere fraction of what it was at 200 meters.

An experiment which will conclusively demonstrate just how serious this decrease is in amplification at the longer wavelengths can be performed with the receiver built in accordance with the instructions contained in Lesson 36.

Perform the experiment as follows: Tune in a station transmitting on a wavelength of 200 to 250 meters with the coupling between P and L2 adjusted so that the R.F. amplifier tube does not quite oscillate. Take careful note of this value of coupling as indicated on its dial. Now tune in another station operating on a wavelength of 450 to 550 meters — the longer the better. When tuning the longer wave station adjust the coupling between P and L2 so that the R.F. tube does not quite oscillate.

Take careful note of the signal strength and then reduce this coupling to the value found best for the 200-meter station. The pronounced decrease in signal strength which accompanies this reduction in coupling is convincing proof of the loss of amplification suffered in a receiver where the coupling between the primary and secondary of the radio-frequency transformer is kept at a sufficiently low value to avoid oscillation at the lower wavelengths in the vicinity of 200 meters. On the other hand, if the coupling is sufficiently close to give good transfer of energy and consequent good amplification at a wavelength, for instance, of 500 meters, the receiver will oscillate as soon as its tuning is reduced to a wavelength, say, of 475 meters.

The principle cause of all this trouble due to oscillation in the radio-frequency amplifier tube is the inter-electrode capacities within the vacuum tube. Of these three inter-electrode capacities; i.e. plate-to-filament, grid-to-filament and plate-to-grid, the plate-grid capacity is the most troublesome inasmuch as it is through this capacity that the feedback from plate to grid circuits, takes place in amounts sufficient to cause oscillation. This plate-grid capacity is indicated in dotted lines as Cpg in Figure 1.

Through this plate-grid capacity of the tube, feed-back from plate to grid circuits takes place and the feed-back voltage thus introduced into the grid circuit is sufficient to cause vigorous and persistent oscillation when the conditions already set forth prevail; i.e., when the plate and grid circuits are tuned to resonance with each other (as they must be

in order to receive a signal at all) and when the coupling between the primary P, and secondary L2, of the radio-frequency transformer is close enough to effect a really good transfer of energy from primary to secondary.

Nevertheless, such a close degree of coupling can be used and yet oscillation avoided by adjusting the circuits so that a state of electrical balance exists between plate and grid circuits of the radio-frequency amplifier tube. When such a balance is secured the coupling between primary and secondary of the radio-frequency transformer may be made sufficiently close to insure good amplification throughout the wavelength range of the receiver with complete freedom from oscillation.

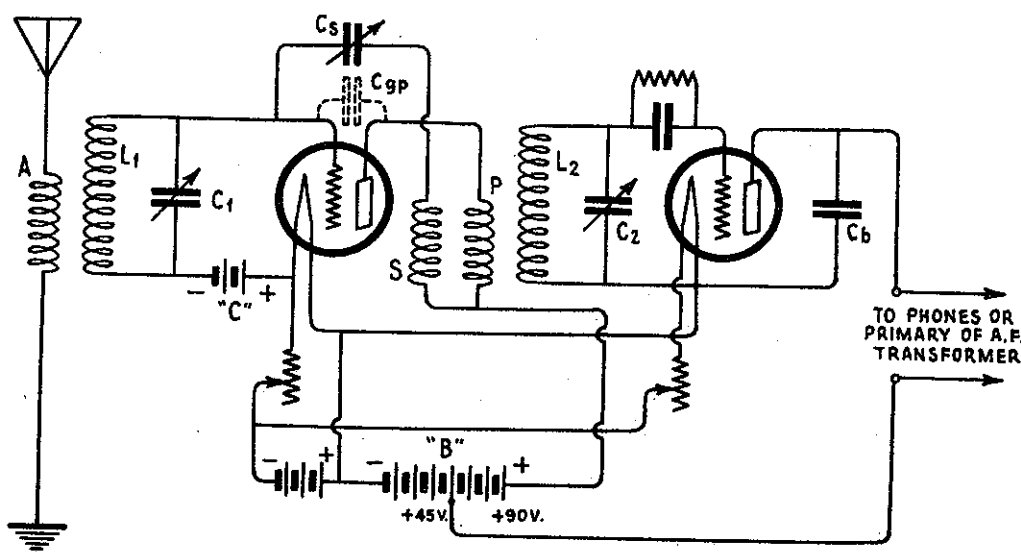


Figure 2

The method employed to obtain this desirable freedom from oscillation is as ingenious in its conception as it is simple in its application. It can be briefly summarized as follows: At the instant the feed-back voltage is fed back from the plate circuit to the grid circuit via the plate-grid capacity, C_{pg} —to introduce into the grid circuit another voltage exactly equal to the feed-back voltage in strength, but of opposite polarity. Being of the same strength as the troublesome feed-back voltage and of opposite polarity this second voltage will counter-act the feed-back voltage and completely nullify it. By thus nullifying the feed-back voltage we remove the cause of oscillation and a stable, non-oscillating and efficient radio-frequency amplifier is the result.

The manner in which this is accomplished is shown in Figure 2. It will be noticed that this diagram is the same as that of Figure 1 except that another coil, "S", has been included and this coil is closely coupled to the primary P. In actual practice this close coupling between these two coils is secured by winding coil S upon the same form as P and in close proximity to it, there being no space between the windings. As a matter

of fact the two coils appear to be, and may be considered as being, a single coil tapped at its center for the "B" battery connection. Needless to say, the slightest variation in the current flowing through coil P will induce in coil S a voltage; and it is this voltage which is used to counter-act the feed-back taking place through the plate-grid capacity of the tube. This "stabilizing" voltage, as it is termed, is applied to the grid through the small variable condenser Cs. When, at any given instant, the flow of radio-frequency current in the plate circuit causes a voltage of positive (+) polarity to be fed back to the grid, this same current flowing through coil P induces in coil S a voltage which when impressed upon the grid through condenser Cs, is of negative (-) polarity. At the next instant when the radio-frequency current flowing in the plate circuit reverses, it consequently reverses the voltage fed back to the grid through the tube capacity to negative, and this same reversal in the radio-frequency current flowing in the plate circuit, and hence in coil P, causes a reversal in the voltage induced in coil S which, when applied to the grid through Cs, is of opposite (positive) polarity. It is in this manner that the counter voltage or "stabilizing" voltage, is secured and applied to the grid of the tube so that at every instant the feed-back voltage taking place through the tube's plate-grid capacity finds itself opposed by a voltage opposite in polarity. If these two voltages are equal in value then, as they are of opposing polarity, one completely counteracts the other and hence their total effect is nil. This is done by making the stabilizing voltage the equal of the feed-back voltage by adjustment of the small condenser Cs. As this condenser is variable it serves as the means of increasing or decreasing the stabilizing voltage until it equals the feed-back voltage and when this adjustment is secured the feed-back voltage will be completely nullified by the stabilizing voltage. Inasmuch as the feed-back voltage is the cause of oscillation, when its effect is cancelled by an equal amount of stabilizing voltage the cause of oscillation is removed and the result is a stable, non-oscillating radio-frequency amplifier.

The condition of electrical balance which exists between plate and grid circuits of the radio-frequency amplifier tube when such an adjustment is secured is given in the following equation.

$$\frac{P}{S} = \frac{C_s}{C_{pg}}$$

Before complete stabilization can be secured the conditions of this equation must be satisfied. For example, if coils P and S are equal then the capacity of Cs must be made equal to that of Cpg in order to stabilize the radio-frequency amplifier tube; if S is only one-half as large as P, then Cs must be made twice as large as Cpg; if S is twice as large as P, then Cs must be one-half as large as Cpg, and so on.

It can be readily appreciated that coil S serves to provide us with a source of stabilizing voltage only approximately of the correct value and this voltage is then adjusted to exactly the correct value by means of condenser Cs. However, it is not at all necessary to use a separate and distinct coil such as S in order to secure a voltage suitable to stabilizing purposes. We already have a coil coupled to the primary P, namely,

the secondary coil L2, and although L2 is primarily for the purpose of coupling to the grid circuit of the detector tube, there is no reason why it cannot be used at the same time as a source of stabilizing voltage and in this way dispense with coil S. This is the method followed in the receiver of this lesson and this minor change in the circuit is shown in the schematic diagram of Figure 3. The primary P, of the radio-frequency transformer is coupled to that end of the secondary winding L2 which is connected to the filament circuit. The stabilizing tap S, is made at about 15 turns from the filament end of the secondary winding. This 15-turn section of the secondary then acts in the same manner as coil S in Figure 2, and in this way dispenses with the need of an additional coil such as S.

The number of turns included between the filament end of the secondary L2, and the stabilizing tap S, (15 turns in this instance) will determine the amount of stabilizing voltage available for balancing purposes. The stabilizing voltage thus secured need be only approximately the right value necessary for complete stabilization inasmuch as the small stabilizing condenser Cs serves the purpose of adjusting the stabilizing voltage to precisely the right value. Hence, the placement of the stabilizing tap S need not be of prime accuracy because any change in the value of its

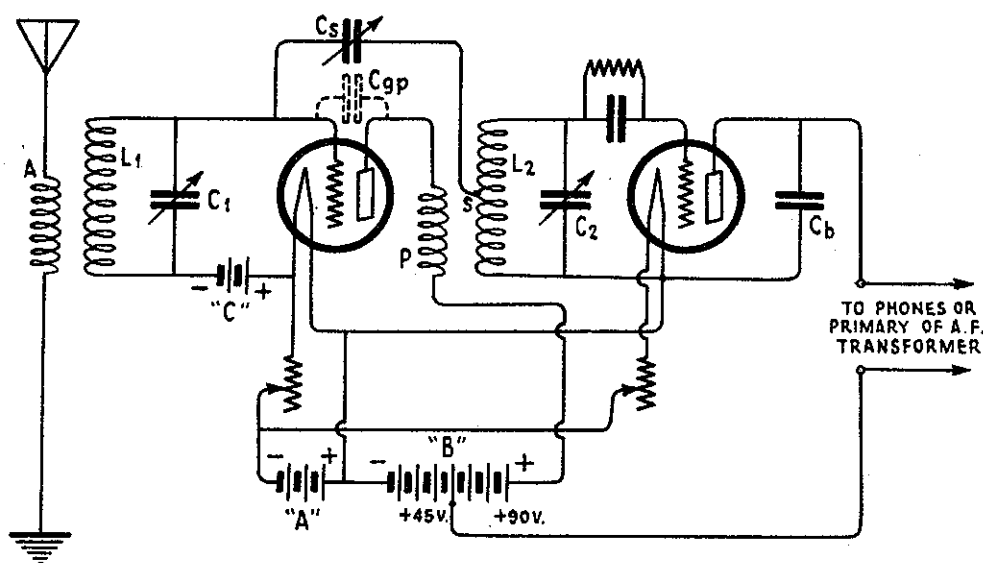


Figure 3

stabilizing voltage caused by shifting the position of this tap several turns along the coil can be compensated for by the small variable condenser Cs.

The equation $P/S = C_s/C_{gp}$, indicative of the conditions necessary to secure an electrical balance in the circuit of Figure 2, applies equally well to the circuit of Figure 3; keeping in mind, however, that in the latter circuit a section of the secondary has been substituted for the separate stabilizing coil of Figure 2.

The layout of the apparatus in this receiver is the same as that in Lesson 36; moreover, the circuit is the same as in that lesson except that in the receiver in this lesson stabilization has been added to the radio-frequency amplifier to insure freedom from oscillation.

The first step is to mount the small stabilizing condenser as near as possible to the grid terminal of the radio-frequency amplifier tube socket. If a small brass angle is obtainable it should be screwed to the baseboard adjacent to the grid terminal of this socket and the stabilizing condenser fastened to this brass angle. If a brass angle is not available a short length of stiff copper wire may be soldered to the grid terminal of the socket, forming a support to keep the stabilizing condenser a short distance above and clear of the baseboard.

The stabilizing condenser furnished with the kit has two sets of stator plates of two plates each, and a single rotor plate. Only one set of stator plates is used, however, and this should be connected to the grid terminal of the tube socket.

Now let us turn our attention to the "picture" wiring diagram on page 5 of Lesson 36. Therein is a drawing of the "three-circuit tuner" which in the receiver of this lesson functions as the tuned radio-frequency transformer P-L2. Along the lower edge of this device is a row of five terminals and now, beginning with the terminal furthest to the left, number these terminals 1,2,3,4 and 5.

Disconnect the wires that are soldered to the tickler coil terminals and connect these two wires instead to the lower terminals 1 and 2. By making this change this movable coil ceases to be the primary of the radio-frequency transformer as it was in Lesson 36, and the smaller of the two fixed coils now becomes the primary. No other connections are made to the movable coil's terminals as this coil is not used in the receiver of this lesson.

Now reverse the leads connected to terminals 4 and 5. That is, the wire now connected to terminal 5 is connected instead to terminal 4, and the wire which was until a moment ago connected to terminal 4 is now connected to terminal 5.

The connections are completed by connecting the center terminal, number 3, to the rotor of the stabilizing condenser Cs. We are now ready to tune the receiver to a transmitting station and adjust it for stabilization.

The tuning of this receiver is the same as that of Lesson 36 except that the variable control of coupling between the primary and secondary of the radio-frequency transformer is eliminated inasmuch as a fixed coil is now being used for the primary winding. Tuning is accomplished by adjustment of the two variable tuning condensers and, when the receiver is resonated to a specific wavelength, the dials mounted on the condenser shafts should read alike, or nearly so.

To stabilize the stage of radio-frequency amplification, proceed as follows: Set the stabilizing condenser at minimum capacity and then tune the receiver

to a station that comes in with good volume - the louder the better. This station should be operating on a wavelength preferably of about 300 meters. The received signal should be heard as a squeal due to the oscillation of the radio-frequency amplifier tube resulting from its lack of stabilization. Now open the filament circuit of the radio-frequency amplifier tube by disconnecting the wire connected to one of the filament terminals of its socket. This permits the rest of the tubes to remain lighted and, even with the radio-frequency amplifier tube turned off, the signal should still be heard - much weaker, of course, yet audible when using the headphones. Do not use a loudspeaker - headphones only will prove satisfactorily in securing accurate adjustment of stabilization in this or any other receiver where stabilization is employed. The signal should still be heard due to the fact that the plate-grid capacity of the radio-frequency amplifying tube now acts as a very small coupling capacity which serves to pass a small amount of the signal energy in the grid circuit of the radio-frequency amplifier tube to its plate circuit and thence, by inductive coupling between P and L2, to the grid circuit of the detector tube. Note that if this plate-grid capacity did not exist the signal would be unable to get through to the detector tube and hence would be inaudible. The capacity of the stabilizing condenser should now be slowly increased until a point is reached where the signal begins to weaken and finally disappears entirely.

That the signal can no longer be heard indicates that the capacity of the stabilizing condenser has been adjusted to such a value that it completely counter-acts the capacity existent between the plate and grid of the tube. (Note: It is at times impossible to get absolute zero signal strength, but for all practical purposes we consider the result as zero signal strength). The effect of the plate-grid capacity of the tube having thus been counter-acted, or balanced out, the stage of radio-frequency amplification is said to be stabilized. The disconnected filament lead is now re-connected to the filament terminal of the tube socket from which it was removed. Signals can now be received with normal volume and the radio-frequency amplifier tube will be stable in its operation; i.e., it will not oscillate.

The stabilizing condenser should be equipped with an insulating knob or handle in order that the body-capacity effect that would result from bringing the hand in close proximity to such highly sensitive portions of the circuit will not influence the accuracy of adjustment of the stabilizing condenser.

The foregoing method is the best to use when stabilizing a receiver in which are incorporated two or more stages of tuned radio-frequency amplification. Beginning with the first stage the method is applied to each successive stage until the amplifier as a whole has been stabilized.

In a receiver such as this where but one stage of tuned radio-frequency amplification is used a slightly different procedure may be resorted to - one which is simpler in its application and fully as effective as the method first described.

In this method the filament of the radio-frequency amplifier tube is allowed to remain lighted. The capacity of the stabilizing condenser

is gradually increased until a setting is reached at which the tube stops oscillating. Continue to increase the capacity of this condenser until the tube again begins to oscillate, then reduce its capacity to a value midway between these two settings. This will be the value of capacity necessary to effect complete stabilization of the tube. It is quite possible that varying the capacity of the stabilizing condenser will have a slight effect upon the tuning of the receiver, so that while adjusting this condenser to its correct value it may be necessary to make slight readjustments of the two tuning condensers.

When the instructions contained in this lesson are carefully carried out, it will be found possible to effect complete stabilization of the radio-frequency amplifier tube, and the receiver will function with complete freedom from oscillation.

EXAMINATION - LESSON 48

1. What is the purpose of condenser Cs?
2. What is the purpose of coil S in Figure 2?
3. Why is it necessary to use "stabilization" in an R.F. amplifier?
4. How is "stabilization" accomplished?
5. What is the principle source of feed-back?
6. In what way does the coupling between P and L2 affect oscillation?
7. Why cannot oscillation be overcome by detuning circuit L2C2?
8. What is meant by "losser" method?
9. What is meant by "stabilization" method?
10. What is the purpose of tap S on the secondary coil, L2?